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Links between adolescent sympathetic and parasympathetic nervous system functioning and interpersonal behavior over time☆

Lisa M. Diamond *, Matthew R. Cribbet

University of Utah, United States

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ABSTRACT

Extensive research has investigated links between individual differences in youths' autonomic nervous system (ANS) functioning and psychological outcomes related to emotion regulation, yet little of this research has examined developmental change. The study tested whether individual differences in youths' tonic and stress-induced ANS functioning, assessed at age 14, and changes in ANS functioning from age 14 to 16 predicted corresponding changes in youths' behavioral warmth, as displayed during videotaped mother-child conflict interactions conducted at age 14 and 16. Increased behavioral warmth was predicted by increased baseline respiratory sinus arrhythmia (RSA), increased SCL stress reactivity, decreased RSA stress reactivity (i.e., greater vagal suppression), and decreased baseline SCL. There was also an interaction between RSA stress reactivity at age 14 and changes in maternal warmth from age 14 to 16, such that increased maternal warmth was only associated with increased adolescent warmth for adolescents with lower RSA stress reactivity at age 14.

1. Introduction

Extensive research over the past several decades has investigated links between individual differences in youths' autonomic nervous system (ANS) functioning and a range of psychological and interpersonal outcomes related to emotional reactivity and regulation. This literature is characterized by considerable diversity regarding which branch of the ANS is assessed (sympathetic, parasympathetic, or both), the specific parameter that is assessed (baseline levels, stress-induced reactivity, or both), the outcomes of interest (social behavior, psychosocial adjustment, etc.), and the age group assessed (young children, pre-adolescents, adolescents, and young adults). As a result of this diversity, it has been difficult to draw straightforward conclusions about linkages between autonomic nervous system functioning and youths' social and psychological functioning. Yet perhaps most notably, little research has explicitly addressed questions of developmental change. Previous research has documented substantial developmental change in youths' capacities for emotion regulation during early and middle adolescence, and in the interpersonal behaviors that depend upon these capacities (Chapman et al., 2010; Gullone et al., 2010; Hare et al., 2008; Silvers et al., 2012; Somerville et al., 2010; Yap et al., 2007). Yet little is known about whether developmental changes in youths' interpersonal behavior are directly related to corresponding changes in sympathetic and parasympathetic nervous system functioning. The present research answers this question. We assessed baseline and stress-induced SNS and PNS functioning in a group of 82 adolescents at age 14 and age 16, using identical assessment procedures. At each assessment, we also evaluated youths' and their mothers' behavioral warmth toward one another during a laboratory-based conflict discussion (reflecting a capacity to maintain prosocial and positive engagement during a stressful and affectively negative interaction). Hence, our data permit us to examine how developmental change in youths' behavioral warmth is related to corresponding developmental change in baseline and stress-induced SNS and PNS functioning.

1.1. Previous research on autonomic functioning and psychosocial adjustment

The ANS has two branches — the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). The SNS is responsible for redistributing metabolic output in times of external threat, and therefore heightened engagement of this system produces the physiological changes most commonly associated with "fight-or-flight" responses to stress, such as increased cardiac output, widespread vasoconstriction, and changes in blood flow to the skeletal muscles, myocardium, brain, kidneys, gastrointestinal tract, and skin. In contrast, the PNS is responsible for maintaining normal growth and restoration of internal organs, processes that are suspended in times of intense stress. Thus, heightened engagement of the PNS produces physiological changes typically associated with relaxation, such as decreases in

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* Corresponding author at: Department of Psychology, University of Utah, 380 South 1530 East, room 502, Salt Lake City, UT 84112-0251, United States.
E-mail address: diamond@psych.utah.edu (L.M. Diamond).

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heart rate and blood pressure. These changes redistribute metabolic energy toward normal maintenance of internal organs and reestablish homeostasis.

Stable individual differences have been detected for both SNS and PNS functioning (Alkon et al., 2003; El-Sheikh, 2007; Fowles et al., 2000). These differences, which appear to have both genetic and early-environmental determinants (Cheng et al., 1997; Healy, 1992; Matthews et al., 1988; Tuvblad et al., 2010), have shown reliable associations with children and adolescents' emotional and interpersonal behavior, and researchers have postulated that this is because individual differences in ANS functioning index individual differences in capacities for emotion regulation, which encapsulates the range of internal and transactional processes through which individuals consciously or unconsciously modulate the experience or expression of emotions elicited by environmental events (Eisenberg et al., 2000; Gross, 1999; Thompson, 1994). The progressive mastery of a diverse range of strategies for emotion regulation is considered a core developmental task for both children and adolescents (Collins et al., 1998; Denham, 2006; Eisenberg & Fabes, 1992; Eisenberg et al., 2002; Fox, 1994a; Halberstadt et al., 2001). Because powerful emotions have the potential to disorganize and/or disrupt multiple psychological and behavioral processes, effective modulation of their experience and expression has been considered essential for basic state regulation, social competence, and interpersonal behavior (reviewed in Fox, 1994b). Accordingly, inability to effectively regulate one's own emotions has been linked to a range of interpersonal problems in both childhood and adolescence (Cicchetti et al., 1995; Collins et al., 1998; Cooper et al., 1995; Eisenberg et al., 2001; Frick & Morris, 2004; Kobak & Ferenz Gillies, 1995; Silk et al., 2003).

Individual differences in ANS functioning are thought to relate to interpersonal behavior because they index individual differences in capacities for stress- and emotion-regulation. For example, Thayer and Lane's (2000) neurovisceral integration model and Porges' Polyvagal Theory (Porges, 2003) suggest that PNS activity, in particular, undergirds the constellation of self-regulatory and affect-regulatory processes that are fundamental to adaptive socioemotional functioning. Generally, vagal activity provides a constant “brake” on cardiovascular functioning (“vagal” refers to the functioning of the 10th cranial nerve, which provides inhibitory input to the heart via the parasympathetic nervous system and plays a critical role in regulating metabolic output in response to environmental events). This tonic inhibitory control permits rapid and efficient modulation of cardiovascular activity in the service of changing environmental demands. Whereas SNS influences on heart rate are relatively slow-acting, typically taking several seconds, vagal inhibition can be suspended in a matter of milliseconds (Saul, 1990). Hence, individuals with greater PNS regulation of heart rate (often denoted vagal tone, and assessed via resting levels of respiratory sinus arrhythmia, or RSA) are conceptualized as having nervous systems that flexibly react to and recover from environmental stressors (Calkins, 1997; DeGangi et al., 1991). This facilitates effective coordination of expressive and affective behavior in the service of social engagement (Porges, 2003).

Numerous studies have provided empirical support for this model. For example, infants with low vagal tone show poor emotional control (Fox, 1989; Porges, 1991) and high behavioral inhibition (Snidman, 1989). Children and adults with low vagal tone show ineffective behavioral coping in response to stress (Fabes & Eisenberg, 1997; Fabes et al., 1993), as well as higher levels of anger, hostility, mental stress, and generalized anxiety (reviewed in Brosschot & Thayer, 1998; Friedman & Thayer, 1998; Horsten et al., 1999). Although the majority of research on affect regulation and the PNS has focused on vagal tone, an increasing body of research assesses PNS activity during stress and other environmental demands. Polyvagal Theory (Porges, 2001) suggests a normative, adaptive pattern of reduced RSA (often denoted vagal suppression) during stress, which functions to promote mobilization of energy and attention toward the task at hand by allowing for a rapid and efficient increase in heart rate without requiring energy-costly SNS mobilization. Vagal suppression has been observed in numerous studies of children, adolescents, and adults engaged in stressful or affectively negative tasks (Beauchaine, 2002; Beauchaine et al., 2001; Pieper et al., 2007), and studies suggest that individuals with greater reductions in RSA during stress have more adaptive patterns of emotional and interpersonal functioning (El-Sheikh & Buckhalt, 2005; El-Sheikh & Whitson, 2006; Hessler & Katz, 2007; Huffman et al., 1998; Moore & Calkins, 2004).

Individual differences in the sympathetic nervous system have also shown significant associations with emotional reactivity and regulation. For example, excessive reactivity in the SNS system, typically indexed by skin conductance (SCL) reactivity to laboratory stressors, has been posited as a potential marker of children's hypersensitivity to environmental challenges (Boucsein, 1991). Accordingly, heightened SCL reactivity predicts a variety of child and adolescent psychosocial outcomes, including reactive aggression (Hubbard et al., 2004; Hubbard et al., 2002), anxiety (Weems et al., 2005), shyness and inhibition (Kagan et al., 1987), emotional disorders (Garralda et al., 1991), and internalizing and externalizing problems (El-Sheikh, 2005a; El-Sheikh et al., 2007). In contrast to these reactivity effects, low SNS activity at baseline has been found to predict heightened risk for outcomes such as aggression and conduct problems (Beauchaine et al., 2007; Crowell et al., 2006; Lorber, 2004; Raine et al., 1990).

1.2. Developmental change

Although studies have found support for this basic model in samples of children, adolescents, and adults, there has been little direct investigation of developmental change in ANS functioning and whether it relates to developmental change in interpersonal behavior. Adolescence is an important period of time for the development and consolidation of emotion regulation skills, given the increasing self-regulatory demands posed by adolescents' changing social roles and their increasingly complex social relationships. Youths typically seek increased autonomy and independence from parents from 13 to 18 years of age, and as a result, their interactions with parents tend to be characterized by heightened tension and negativity and more intense emotional reactivity during this stage of life, thereby increasing their day to day self-regulatory demands (Allen & Land, 1999; Allen et al., 2002; Collins et al., 1998; Conger & Ge, 1999; Cooper et al., 2004; Larson et al., 1999; Steinberg & Morris, 2001). Finally, contrary to the notion that youths' basic physiological capacities for affect regulation are “finished” developing, studies show that maturation of neural regions in the prefrontal cortex involved in affect regulation continued to undergo development and maturation well into late adolescence (Somerville et al., 2010; Spear, 2000). Accordingly, adolescents show a variety of developmental changes that facilitate improved emotion-regulation and interpersonal functioning, such as cognitive reappraisal, self-reflection, perspective-taking, response-inhibition, and sensitivity to environmental cues (Silvers et al., 2012; Somerville et al., 2010; Steinberg, 2005; Yap et al., 2007). Hence, this is a period of time during which individual differences in the basic ANS substrates for emotion regulation might be expected to have notable implications for youths' interpersonal behavior.

Furthermore, evidence suggests that these basic ANS substrates also undergo a certain degree of developmental change. Although both SNS and PNS functioning are generally treated as stable individual difference dimensions, they have been found to exhibit malleability (especially in response to stress) from childhood to early adolescence (Alkon et al., 2011; Hinnant et al., 2011; Salomon, 2005; Vasilev et al., 2009). The degree to which changes in autonomic parameters represent normative developmental transitions versus specific adaptations to environmental challenges is unknown, given how little is known about the normative developmental course of